



## BACKGROUND OF THE INVENTION

The present invention relates to an improved coiled tubing injector. More particularly, the present invention relates to a coiled tubing injector mounted on a mobile frame with means for an adjustable, quick change of a storage reel or spool, means for varying the holding pressure of coiled tubing against the injection reel, and means for angular injection of coiled tubing into a wellhead.

The general background relating to coiled tubing injector units is described in the inventor's previous U.S. Pat. No. 4,673,035 which is incorporated herein by reference for all purposes.

It has been found that by increasing the degree of wrap of the coiled tubing around the injector reel and by being able to adjust the amount of pressure applied against the tubing at various locations around the wrap, injection of the tubing into the wellhead is improved. Greater depths of injection may be achieved much more quickly.

Further, there has been a need to accommodate various widths and diameters of tubing storage spools. Considerable time and effort are expended in the removal and replacement of a spent storage spool. By providing a means to quickly change the spool and to adjust for a different spool width or diameter (diameter being generally understood as flange height of a spool), the present invention increases productivity and reduces the cost of operation.

1 Angular or horizontal well drilling has become an  
2 increasingly important feature in oil and gas production as  
3 well as in environmental remediation procedures. There has  
4 developed a need to be able to inject extensive runs of coiled  
5 tubing (1000-2000 feet) into shallow, horizontal wellbores.  
6 However, it has been difficult to inject coiled tubing through  
7 the sharp bend of a shallow, horizontal well. The present  
8 invention enables the operator to angularly inject coiled  
9 tubing into such a wellhead. The increased wrap of the coiled  
10 tubing around the injector reel with the capability of being  
11 able to adjust the pressure on the wrapped tubing provided by  
12 the present invention further improves the ability of the  
13 operator to inject coiled tubing into a shallow, horizontal  
14 wellbore.

#### 15 SUMMARY OF THE INVENTION

16 The improvements in coiled tubing injection provided by  
17 the present invention are achieved by a unique arrangement of  
18 structural elements. A mobile frame accommodates a cradle  
19 which supports a coiled tubing storage spool. The cradle may  
20 be provided with a traversing mechanism which allows the  
21 storage spool to slidably reciprocate across the frame during  
22 the return of coiled tubing to the spool to distribute the  
23 tubing evenly on the storage spool. The cradle has a pair of  
24 opposed pivotable bullnose arms which engage openings in the  
25 spool side wall or flange and allow the spool to rotate. The

1 arms are slidably adjustable both horizontally and vertically  
2 to accept spools of varying widths and diameters within the  
3 same cradle. A mast is pivotably attached to the frame to  
4 raise and lower an injector reel rotatably mounted on an  
5 opposite end of the boom arm from a first stored position to  
6 a second tubing injection position. A drive mechanism is  
7 attached to the injector reel to rotate the injector reel to  
8 dispense or retrieve the coiled tubing. The injecting  
9 position results in the injector reel being generally  
10 positioned to inject the coiled tubing into a well or hole in  
11 the earth's surface. The injecting position may be vertical  
12 or generally 90° to the earth's surface or it may be angled at  
13 less than 90° to facilitate injection into a shallow  
14 horizontal well depending upon the embodiment utilized. A  
15 separate drive is provided for the storage spool to cooperate  
16 with the injector reel in injecting or retrieving the coiled  
17 tubing. A hold down assembly is mounted around a portion of  
18 the circumference of the injector reel for exerting pressure  
19 against the coiled tubing over more than 90° of injector reel  
20 circumference. The hold down assembly has a multiplicity of  
21 individual hold down mechanisms which enable the operator to  
22 vary the pressure exerted on the coiled tubing at any location  
23 around the circumference of the reel where there is positive  
24 engagement of the tubing with the rollers of the assembly.  
25 The apparatus is provided with coiled tubing straighteners;

1 one of the straighteners in the angular injection mode is  
2 housed within the mobile frame and the other is attached above  
3 the wellbore.

#### 4 BRIEF DESCRIPTION OF THE DRAWINGS

5 The invention will be better understood and objects other  
6 than those set forth above will become apparent when  
7 consideration is given to the following detailed description  
8 of the preferred embodiments. Such description makes  
9 reference to the annexed drawings wherein:

10 Fig. 1 is a side elevation view of the tubing injector  
11 apparatus constructed according to the teachings of the  
12 present invention. The injector reel is positioned in the  
13 stored position.

14 Fig. 2 is a top view of the injector apparatus of Fig. 1.

15 Fig. 3 is a back end view of the apparatus of Fig. 1.

16 Fig. 4 illustrates the bullnose arms of the present  
17 invention in the retracted position to accept a storage spool.

18 Fig. 4A illustrates a standard storage spool of the prior  
19 art.

20 Fig. 5 shows a side elevation view of the apparatus  
21 constructed according to the teaching of the present invention  
22 in a first alternative injecting position.

23 Fig. 6 is a back end view of the apparatus of Fig. 5.

24 Fig. 7 is a side elevation view of an alternative  
25 embodiment of the apparatus of the present invention in the

1 stored position.

2 Fig. 8 is a back end view of the apparatus of Fig. 7.

3 Fig. 9 illustrates a side elevation view of an  
4 alternative embodiment of the apparatus of the present  
5 invention in the angular injection position.

6 Fig. 10 is a back end view of the apparatus of Fig. 9.

7 Fig. 11 is an illustration of a side elevation view of  
8 the storage spool cradle of the present invention with a small  
9 diameter spool shown in broken lines.

10 Fig. 12 shows a side elevation view of the storage spool  
11 cradle of the present invention with the side frames raised to  
12 support a large diameter spool shown in broken lines.

13 Fig. 13 is an end view of the storage spool cradle with  
14 the bullnose arms in the inserted position for a wide spool.

15 Fig. 14 is an end view of the storage spool cradle with  
16 the bullnose arms in the inserted position for a narrow width  
17 spool.

18 Fig. 15 is an end view of the storage spool cradle with  
19 the bullnose arms in the retract position for a wide spool.

20 Fig. 16 is a section view of one of the hold down  
21 mechanisms constructed according to the teachings of the  
22 present invention.

#### 23 DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

24 It should be understood by one of ordinary skill in the  
25 art that much of the basic operation of the present inventive

1 coiled tubing injection apparatus is detailed in U.S. Pat. No.  
2 4,673,035 which is incorporated herein by reference for all  
3 purposes. The instant description emphasizes the improvements  
4 to the present apparatus over U.S. Pat. No. 4,673,035.

5 Referring to Fig. 1, there is shown a preferred  
6 embodiment of the present invention indicated generally at  
7 reference 10. In the embodiment shown in Fig. 1, the  
8 apparatus 10 is mounted on a trailer but could be mounted to  
9 a truck (not shown) or on a separate frame (not shown) which  
10 could be slid or lifted onto or off of a truck or trailer. As  
11 shown in Fig. 1, the apparatus 10 is mounted on a mobile frame  
12 having wheels 14 and a control cabin 16.

13 A coiled tubing storage reel or spool 18 is mounted on a  
14 cradle 20, and coiled tubing 22 is stored thereon. The cradle  
15 20 is attached to a traversing mechanism (not shown) as  
16 described in U.S. Pat. No. 4,673,035, which allows the cradle  
17 20 to be reciprocated perpendicularly to the axis of the frame  
18 12. Spool side frames or supports 24 are slidably affixed to  
19 the cradle 20 by telescoping connections 25 and 27 so that the  
20 opposed bullnose assemblies 26 may be moved closer together or  
21 further apart depending upon the width of the particular  
22 storage spool being used (see Figs. 13 and 14). Spool side  
23 supports 24 and the corresponding bullnose assemblies 26 may  
24 be pivoted outwardly as shown in Fig. 15 to retract the  
25 bullnose assemblies from the storage spool. Hydraulic

1 cylinders 30 are utilized to urge the supports 24 outward  
2 about pivot joints 28.

3 Fig. 4 illustrates the quick placement of a storage reel  
4 or spool 18, by rigging the spool to spreader bar 32 with  
5 chain 33. The bullnose assemblies 26 are pivotally retracted  
6 to enable the spool to be removed or installed.

7 Turning again to Fig. 1, injector reel 34 is shown in the  
8 stored position at the front end 36 of the frame 12. Reel 34  
9 is rotatably attached to one end of boom arm or mast 38. Mast  
10 38 is attached at hinge member 40 to mast riser 42. Mast  
11 riser 42 is attached to the back end 44 of frame 12.

12 Injector reel 34 is further provided with a drive  
13 mechanism 46 which includes a hydraulic drive motor 48, a  
14 drive chain linkage 50, and sprocket assembly 52 extending  
15 circumferentially around the injector reel 34.

16 Reel support frame 190 also extends circumferentially  
17 around the reel 34 and supports the straightener assembly 54  
18 and the hold down assembly 56. Hold-down assembly 56 consists  
19 of a multiplicity of separate hold down mechanism 58. In the  
20 preferred embodiment twenty hold-down mechanisms are mounted  
21 around a portion of the circumference of the injector reel 34  
22 to exert pressure against the coiled tubing over more than 90°  
23 of the injector reel circumference. Fig. 5 illustrates the  
24 degree of wrap that is provided by the hold-down assembly 56  
25 when the injector reel 34 is in the tubing injection position.



1           Also shown in Fig. 1 is the hydraulically activated  
2 elevating work floor [58] 59, leveling cylinders 60, swing  
3 lock 62, mast lift cylinder 64, and storage spool drive  
4 mechanism 66.

5           Fig. 2 illustrates a top view of the apparatus 10 with  
6 the storage spool 18 and cradle 20 centered on the frame 12  
7 traverse mechanism. The injector reel 34 is in the stored  
8 position at the front end of the frame. Fig. 3 is a partial  
9 back end view of the apparatus 10 with a bullnose assembly 26  
10 inserted into the storage spool 18. A lateral positioning  
11 cylinder 68 is shown attached beneath the frame 12 to provide  
12 support and stabilization on uneven terrain.

13           Fig. 5 shows the mast 38 raised by mast lift cylinder 64  
14 to a tubing injection position generally perpendicular to the  
15 frame 12 and at the back end 44 of the frame 12. Swing locks  
16 62 (one on each side of mast 38) have been latched to secure  
17 the mast 38 and injector reel 34 in the uplift position. It  
18 should be noted that in the injecting position coiled tubing  
19 22 extends from the storage spool 18 up and over the injector  
20 reel 34 wrapping the injector reel at an angle or arc greater  
21 than 90°.

22           Hold-down assembly 56 extends around a portion of the  
23 circumference of the injector reel more than 90° to exert  
24 pressure on the coiled tubing as it is injected into the well  
25 or returned to the spool. Tubing 22 exits the apparatus 10  
26 generally perpendicularly to the earth's surface as seen in  
27 Fig. 5. Angle  $A_v$  is generally 90° in when the embodiment of

1 Fig. 5 is in the injecting position. Further, Fig. 5  
2 illustrates that the support frame 24 supporting the bullnose  
3 assemblies 26 may be telescopingly vertically raised or  
4 lowered to accommodate various storage spool diameters. In  
5 Fig. 5 the frame 24 is shown vertically raised to accept a  
6 large diameter spool.

7 The standard spool configuration may be seen in Fig. 4A.  
8 The spool diameter is also called the flange height and is  
9 designated A. The spool core diameter is shown as B while the  
10 spool inside width is designated C and the spool outside width  
11 designated D. The present invention 10 will accommodate a  
12 spool having a diameter A from 90" to 165" and having spool  
13 widths D from 58" to 96".

14 A telescoping tubing stabilizer 70 has an upper section  
15 71 and a lower section 72 as seen in Fig. 5. The stabilizer  
16 70 extends from the straightener assembly 54 to the B.O.P 74  
17 at the wellhead. The function of the stabilizer 70 is to  
18 ensure that the coiled tubing 22 does not bend or excessively  
19 flex as it is being injected.

20 A partial back end view of the injection apparatus 10 is  
21 illustrated in Fig. 6. As may be seen the apparatus is in the  
22 raised injecting position with the injector reel 34 above the  
23 storage spool 18 and frame 12 and generally perpendicular to  
24 the earth's surface 80. The storage spool 18 has been  
25 traversed to the right on the frame 12 and the cradle 20

1 extended to support the spool 18. The reel support frame 190  
2 is shown supporting one of the hold-down mechanisms 58.

3 An alternative embodiment of the present inventive  
4 apparatus 11 is shown in Figs. 7 through 10. In embodiment 11  
5 the frame 12 is mounted on the back of a truck 15. The  
6 injector reel is attached to the frame 12 in front of the  
7 storage spool 18.

8 A pivoting hinge 90 connects an upper frame section 82 to  
9 lower frame section 84. A telescoping mast or boom arm 38 is  
10 pivotally attached to a front end of the lower frame section  
11 84 and the front end of the upper frame section 82. When the  
12 mast is activated the front end of the upper frame section 82  
13 is raised bringing the injector reel 34 above the lower frame  
14 section 84 and the storage spool 18 as seen in Fig. 9.

15 Coiled tubing 22 is directed from the storage spool 18  
16 around the injector reel 34. Both the spool 18 and the reel  
17 34 are provided with drive mechanisms 66 and 46, respectively,  
18 to cause each to rotate to push or pull the coiled tubing 22  
19 into or out of the well as desired.

20 Because of the unique placement and arrangement of the  
21 spool 18, the injection reel 34, the mast 38, and the hinge  
22 90, coiled tubing 22 may be angularly injected into a well or  
23 hole in the earth's surface 80. Fig. 9 shows the apparatus 11  
24 in the injecting position with the coiled tubing 22 exiting  
25 the apparatus 11 at an angle  $A_v$  of less than  $90^\circ$  to the earth's  
26 surface.

1           An additional feature shown in Figs. 7 and 9 and provided  
2           in embodiment 11 is that the straightener assembly 54 and the  
3           stabilizer tube 70 are housed within the upper frame section  
4           82 thereby saving considerable space and assembly time. A  
5           second straightener assembly may be attached to the distal end  
6           92 of the stabilizer tube above the well or hole.

7           Figs. 8 and 10 illustrate partial back end views of the  
8           alternative embodiment 11. Fig. 8 shows one bullnose assembly  
9           26 retracted and the other inserted. Fig. 10 shows the cradle  
10          20 traversed to the right to its maximum extent.

11          As previously discussed cradle 20 is provided with  
12          supports 24 which are adjustable both vertically and  
13          horizontally to accommodate various widths and diameters of  
14          storage spools. Figs. 11 and 15 illustrate these features of  
15          the present invention. Fig. 11 shows a storage spool 18  
16          slidably attached to cradle 20. Support 24 which supports the  
17          bullnose 26 is provided with a hydraulic lifting cylinder 100.  
18          Fig. 11 shows cylinder 100 in the retract or lowered position.  
19          This position allows the operator to insert and remove a  
20          smaller diameter spool. A spool drive mechanism 66 includes  
21          a hydraulic motor 69, a drive chain or belt 65 and spool drive  
22          sprocket 67. An adjustable idler 61 is provided to enable the  
23          operator to vary the length of the drive mechanism to  
24          accommodate various diameter spools as may be required. Fig.  
25          12 illustrates the cylinder 100 in the extended or raised  
26          position to accommodate a larger diameter spool.

1           The horizontal adjustment of the cradle 20 to accommodate  
2           varying spool widths is illustrated in Figs. 13-15. Fig. 13  
3           shows the supports 24 in the extended or wide position.  
4           Sliding connections 25 and 27 allow the supports 24 and  
5           bullnose assemblies 26 to be moved apart. Fig. 14 illustrates  
6           the supports in the narrow position. Finally, Fig. 15  
7           illustrates the bullnose assemblies 26 in the outwardly  
8           pivoted retract position and the supports in the extended  
9           position.

10           The unique hold-down mechanism 58 of the present  
11           invention is shown in Fig. 16. As previously discussed, in  
12           the preferred embodiment twenty of the mechanisms 58 are  
13           positioned around a portion of the circumference of the  
14           injector reel. Each mechanism is provided with a spindle  
15           bracket 200, a spindle 202, a roller 204, and a pressure or  
16           tension adjustment bolt 206.

17           The mechanism is attached to the reel frame 190 as shown  
18           in Fig. 16. By adjusting bolt 206 the roller 204 may be  
19           raised or lowered against the coiled tubing 22 which rides in  
20           groove 210 of roller 204. Bearings 208 and 210 are affixed to  
21           the spindle 202 to allow the roller 204 to rotate. Dust caps  
22           212 and 214 may be provided to protect and seal the bearings.

23           By individually adjusting the pressure of the mechanism  
24           58 against the coiled tubing the operator has greater control  
25           over the injection and retraction process.

1           Although the invention has been described with reference  
2           to a specific embodiment, this description is not meant to be  
3           construed in a limiting sense. On the contrary, various  
4           modifications of the disclosed embodiments will become  
5           apparent to those skilled in the art upon reference to the  
6           description of the invention. It is therefore contemplated  
7           that the appended claims will cover such modifications, alter-  
8           natives, and equivalents that fall within the true spirit and  
9           scope of the invention.